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FINGER DEXTERITY OF THE PRESSURE-SUITED SUBJECT

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FOREWORD

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ABSTRACT

This study attempts to establish an objective baseline for evaluating the functional mobility of pressure gloves. The Purdue Pegboard Dexterity Test was employed to measure hand dexterity under three conditions: (1) subjects barehanded, but wearing an unpressurized A/P-22S-2 full-pressure suit ensemble; (2) subjects gloved (HAK-3/P-22S-2) and suited, but not pressurized; (3) subjects gloved, suited, and pressurized to 2.5 psi. The Purdue Pegboard Dexterity Test has been found to be a delicate indicator of hand dexterity in the test conditions. The test results show a marked reduction in dexterity even with the gloves and suit uninflated, and an additional loss when gloves and suit were inflated. The degree of loss of dexterity is believed to provide an objective measure whereby one operational aspect of pressure gloves may be evaluated.

PUBLICATION REVIEW

This technical documentary report is approved.

Walter F. Grether

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Technical Director
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Dieter E. Walk

INTRODUCTION

The emphasis on handling materials and tools in space, both inside and outside the capsule, has been increasing almost day by day. Hence, it appeared appropriate to take a closer look at one of the factors which will play a major role in any manual task performed in space, ie, the loss of finger dexterity due to the wearing of pressure gloves. Hitherto, there has been no critically objective method of evaluating performance, dexterity, or mobility of gloves directly. The lack of emphasis on this type of evaluation may be explained by the expectation, in many cases, that only gross hand functions are to be accomplished in space, and by unwarranted assumptions that there will be little or no effect on performance caused by the wearing of gloves. For example, Hertzberg (ref 8) has shown that the grip strength of a gloved hand is considerably less than that of a bare hand; and Bradley (refs 2,3) has demonstrated the effect of gloves on hand tactility and performance under various conditions. I believe that the increasing sophistication of techniques and hardware items to be utilized in space forces a reevaluation of existing methods of assessing pressure-glove mobility and dexterity, so that future needs may be met.

The best possible condition of dexterity for any person is that of the bare hand. A glove has no "performance" in itself; therefore, any glove evaluation must be related finally to barehanded tests. If a baseline value of barehanded dexterity for each subject can be established by repeated tests, then the performance decrement due to gloves can be considered to be an impedance caused by new conditions.

The primary purpose of this study, then, is to assess the Purdue Pegboard method as an objective means of evaluating pressure glove mobility, dexterity, and tactility. An additional purpose has been to measure hand dexterity of subjects under three conditions: barehanded; gloved, uninflated; and gloved, inflated.

MATERIALS

In these experiments, the HAK-3/P-22S-2 full-pressure glove was selected because of its wide acceptance in the Air Force as a part of the operational A/P-22S-2 full-pressure ensemble.

The Purdue Pegboard manipulative dexterity test has been chosen from a variety of such tests (refs 5,9,11,12) because the tasks to be accomplished appear to be the most delicate of those surveyed. In other words, the Purdue Pegboard test is probably the most demanding of the tests, and hence constitutes one extreme limit of the tasks capable of being performed in space.* Furthermore, since this test has been performed on thousands of subjects, well-validated profiles of the population are available.

The A/P-22S-2 full-pressure suit ensemble was employed in these tests according to the manner prescribed by the Operation and Service Manual issued by the David Clarke Company. The sizes of these items needed for the 17 subjects are listed in table 1.

TABLE 1

SIZES OF HAK-3/P-22S-2 GLOVES AND A/P-22S-2 SUITS*

	Gloves											
Sizes	A	B	C	D	E	F	G	H	I	J	K	L
No. of Subjects		2	3		3			2	4		3	
	Suits											
Sizes	SR		SL	MR	ML		LR	LL	XLR		XLL	
No. of Subjects	1		4	2	4			1	5			

*References 1 and 4

No ventilating garment was needed in these tests because the subjects were kept comfortably cooled by the air that was fed into the suits through their standard ventilating systems. All tests were conducted at ordinary room temperature.

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*As this report was being prepared for publication, Pierce's paper (ref 10) appeared in March 1964. Although prepared completely independently, the two reports substantiate each other.

THE SAMPLE

Seventeen college men were chosen as a convenient sample to serve as subjects for this test. All were normal, healthy males. None had had experience in wearing pressure suits.

The subjects were measured for the following dimensions:

1. Stature
2. Weight
3. Hand Length
4. Hand Circumference at Metacarpale

They ranged in Stature from 160.5 cm (63.2 inches), the 1st percentile (ref 7), to 183.3 cm (72.2 inches), the 90th percentile; in Weight from 60.6 kg (133.5 lbs), the 5th percentile, to 100 kg (220 lbs), the 99th percentile; in Hand Length from 179 mm (7.0 inches), the 10th percentile, to 207 mm (9.4 inches), the 99th percentile; and in Hand Circumference from 191 mm (7.5 inches) to 230 mm (9.0 inches).* Thus, in these dimensions, they appeared to be a reasonably representative sample of the Air Force population. The first two dimensions were necessary for the proper fitting of the pressure suits, and the last two for the pressure gloves.

TEST CONDITIONS AND METHODS

The three test conditions are as follows:

1. The barehanded subject wore an uninflated A/P-22S-2 pressure suit, with the visor up. See figure 1.

2. The subject wore the uninflated HAK-3/P-22S-2 gloves and the pressure suit with the visor up. See figure 2.

3. The subject wore the suit and gloves inflated to 2.5 psi with the visor down. See figure 3.

Each subject was dressed in the full-pressure ensemble, and individual suit adjustments were made to insure proper fit. During this period each subject was given an oral orientation describing the working principle of the suit, and the subject moved about so as to become familiar with body mobility within the suit. Following this familiarization period, the subject was seated at the test table, the instructions as prescribed by the pegboard test manual were given him, and trials were performed according to condition 1.

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*Hand Circumference at Metacarpale was not included in the 1950 Survey, hence no percentile designations are available for this dimension.

RIGHT HAND

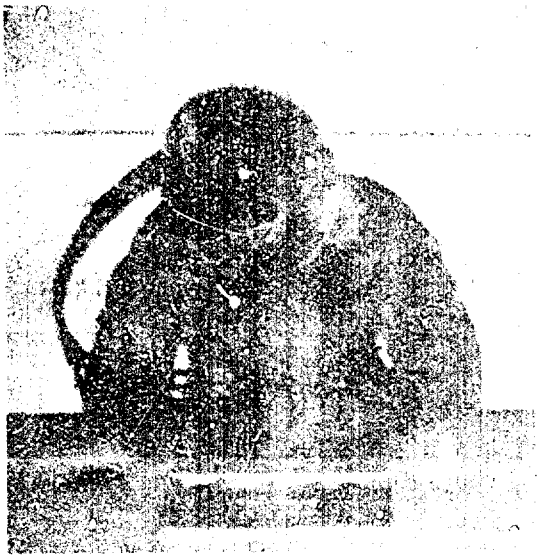
LEFT HAND

BOTH HANDS

ASSEMBLY

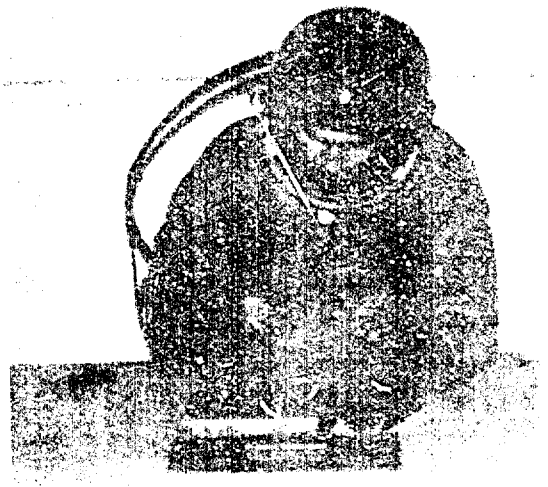
Figure 1. Condition 1: Subject Suited, but Barehanded (Visor Up, Unpressurized)

RIGHT HAND



LEFT HAND

BOTH HANDS



ASSEMBLY

Figure 2. Condition 2: Subject Suited and Gloved (Visor Up, Unpressurized)

RIGHT HAND

LEFT HAND

BOTH HANDS

ASSEMBLY

Figure 3. Condition 3: Subject Suited and Pressurized to 2.5 psi (Visor Down)

Next, pressure gloves were fitted to the subject and were secured to the suit to fulfill condition 2. For each test the monitor (a) pushed the glove fingers onto the subject's fingers to ensure that the subject's fingertips fitted snugly into the glove fingertips, and (b) tightened the adjustable strap buckles on the backs of the gloves to assure retention of maximum snugness. Wearing the complete pressure ensemble, but with the suit unpressurized and the visor up, the subject again performed the standard battery of tests.

For tests to meet condition 3, the subject's visor was closed and the suit was pressurized to 2.5 psi. No further adjustments were made to the pressure gloves during this test condition. Though the A/P-22S-2 full-pressure suit is operationally a 3.5 psi suit, the pressurized trials were conducted at 2.5 psi for two reasons: (a) the major portion of the ballooning or "growth" of the suit and its components has already occurred, and (b) additional pressure results in increased stiffening of the suit cloth, which inhibits movement of the shoulder and elbow and reduces arm mobility, thereby affecting performance. For these pressurized trials the test instructions were followed exactly, except that the pegboard was turned 180° so that mobility restrictions of the pressurized suit would not influence test results (see figures 1, 2, and 3). This 180° rotation brought the board cups close to the subject so that he needed to move only his wrist and fingers, not his entire arm, thereby eliminating a possible variable.

All subjects were tested in the same room, on the same furniture, and were given the same instructions by the same monitors. The only variables for each subject were the test conditions.

RESULTS AND DISCUSSION

Table 2 presents the detailed scores achieved by each of the 17 subjects in each task and condition. Inspection shows that the scores of the three repetitions of each task have low variabilities and that the trend to reduced dexterity is the same throughout.

This trend is more concisely shown by table 3, which summarizes the data of table 2.

By expressing the barehanded data as 100% of the combined subjects' original capability, we establish a constant base of comparison, despite the variability in individual performance. Thus converted, the data show the values in table 4.

Because of the direction and magnitude of the decrement in test scores of the gloved hand, and the further decrement of the pressurized hand, it appears reasonable to consider this test to be a fairly delicate measure of the manipulative capability of the pressure-gloved hand. Of course, every effort was made to provide perfect fit for each subject in the suit and in the gloves, and these were generally excellent. Nevertheless, the 2.5 psi pressurization magnified any slight mis-match between

TABLE 2

DEXTERITY TEST: RAW SCORES

SUBJECT	CONDITIONS	TRIALS*	RIGHT HAND 1	RIGHT HAND 2	RIGHT HAND 3	LEFT HAND 1	LEFT HAND 2	LEFT HAND 3	BOTH HANDS 1	BOTH HANDS 2	BOTH HANDS 3	ASSEMBLY* 1	ASSEMBLY* 2	ASSEMBLY* 3
1	Barehanded		15	14	16	11	14	14	11	11	11	33	40	44
	Gloved, no pressure		6	9	9	8	9	10	5	4	7	16	15	18
	Gloved, 2.5 psi		4	4	4	2	3	5	3	4	2	9	9	6
2	Barehanded		14	15	14	15	16	17	13	13	12	40	39	42
	Gloved, no pressure		10	10	10	9	10	13	8	7	6	12	15	20
	Gloved, 2.5 psi		5	5	7	7	7	7	2	3	3	6	7	3
3	Barehanded		14	15	15	14	16	15	14	13	16	44	46	48
	Gloved, no pressure		7	8	10	5	8	8	5	5	4	12	12	15
	Gloved, 2.5 psi		5	5	2	4	3	5	0	2	2	6	5	6
4	Barehanded		19	15	18	17	17	16	13	13	15	48	45	47
	Gloved, no pressure		11	8	10	10	10	8	8	7	7	17	17	19
	Gloved, 2.5 psi		4	5	3	3	4	4	3	2	1	10	8	11
5	Barehanded		15	16	15	18	17	19	12	14	14	37	28	36
	Gloved, no pressure		12	13	11	12	13	12	9	11	11	18	20	15
	Gloved, 2.5 psi		8	8	6	7	7	5	4	3	4	12	7	16
6	Barehanded		17	16	19	17	16	15	13	13	13	38	44	47
	Gloved, no pressure		8	7	11	8	9	10	7	5	7	15	17	14
	Gloved, 2.5 psi		3	6	5	3	6	3	1	3	3	8	6	8
7	Barehanded		16	16	18	14	17	14	14	14	15	34	34	44
	Gloved, no pressure		13	13	13	10	12	13	10	9	9	16	18	22
	Gloved, 2.5 psi		8	7	5	5	7	6	4	4	4	10	4	7
8	Barehanded		17	18	19	15	17	18	14	14	13	36	43	43
	Gloved, no pressure		12	14	15	13	12	13	8	7	10	21	20	22
	Gloved, 2.5 psi		6	5	7	5	5	6	4	1	3	8	13	14
9	Barehanded		18	20	20	16	17	19	13	15	16	46	48	51
	Gloved, no pressure		15	15	16	14	13	14	10	10	9	27	27	26
	Gloved, 2.5 psi		10	8	8	9	6	8	6	4	5	12	14	13
10	Barehanded		15	16	16	14	16	17	11	14	11	38	33	40
	Gloved, no pressure		12	13	13	14	13	12	7	8	9	17	18	18
	Gloved, 2.5 psi		8	8	7	8	6	6	3	2	3	6	10	10
11	Barehanded		15	16	17	15	15	16	13	12	13	31	41	45
	Gloved, no pressure		12	13	12	12	11	12	8	8	8	17	24	27
	Gloved, 2.5 psi		7	7	8	6	7	8	3	5	5	10	10	12
12	Barehanded		15	17	19	16	18	17	14	15	16	40	43	46
	Gloved, no pressure		12	12	13	11	12	13	8	9	8	16	17	22
	Gloved, 2.5 psi		6	5	6	7	9	9	4	3	5	6	10	14
13	Barehanded		16	15	17	17	19	18	14	16	14	31	40	42
	Gloved, no pressure		4	8	7	9	7	7	3	4	4	12	14	11
	Gloved, 2.5 psi		3	3	4	4	4	4	0	3	1	2	6	5
14	Barehanded		16	15	18	16	16	16	15	14	16	46	51	56
	Gloved, no pressure		8	10	11	7	10	8	7	6	8	22	21	23
	Gloved, 2.5 psi		7	7	7	7	8	7	3	5	2	4	3	6
15	Barehanded		17	17	18	15	17	17	14	14	15	45	49	52
	Gloved, no pressure		10	11	12	8	8	12	7	7	4	22	21	19
	Gloved, 2.5 psi		4	6	7	9	7	8	5	3	3	10	14	15
16	Barehanded		16	14	17	16	18	18	12	14	14	45	45	56
	Gloved, no pressure		10	9	10	11	9	11	7	7	8	22	25	27
	Gloved, 2.5 psi		6	8	7	7	4	4	2	2	4	10	9	14
17	Barehanded		17	21	18	18	18	19	14	15	17	44	53	49
	Gloved, no pressure		9	9	10	6	8	5	4	4	5	16	14	10
	Gloved, 2.5 psi		4	5	4	3	2	2	1	1	1	6	4	5

* Terminology in this report follows that of the Purdue Pegboard instructions (ref 13).

TABLE 3

DEXTERITY TEST SUMMARY: MEANS OF 17 SUBJECTS

Conditions	Right Hand	Left Hand	Both Hands	Assembly
Barehanded	49.5	49.0	41.0	128.7
Gloved, no pressure	32.2	30.6	21.3	55.3
Gloved, 2.5 psi	17.5	16.9	8.7	25.8

TABLE 4

DEXTERITY TEST SUMMARY IN PERCENT (N = 17)

Conditions	Right Hand	Left Hand	Both Hands	Assembly
Barehanded	100%	100%	100%	100%
Gloved, no pressure	65%	63%	52%	43%
Gloved, 2.5 psi	35%	35%	21%	20%

the subject's body size and suit size, and between his hand size and glove size, because the resulting expansion in either case tended to force the fingertips of the glove away from the fingertips of the subject. Another factor was the stiffening of the pressure suit, and especially the glove fingers under pressure, increasing the muscular effort necessary to perform the tasks. Both factors combined to reduce the subject's dexterity.

CONCLUSIONS

1. The Purdue Pegboard Test is considered to be a fairly delicate test of the hand dexterity of a subject wearing the HAK-3/P-22S-2 pressure gloves.

2. A pressure-suited subject wearing those gloves unpressurized must expect a decrement to about 65%, or less, of his ungloved dexterity in such tasks.

3. The subject pressurized to 2.5 psi in the specified equipment must expect a further decrement to about 35%, or less, of his ungloved dexterity in such tasks.

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